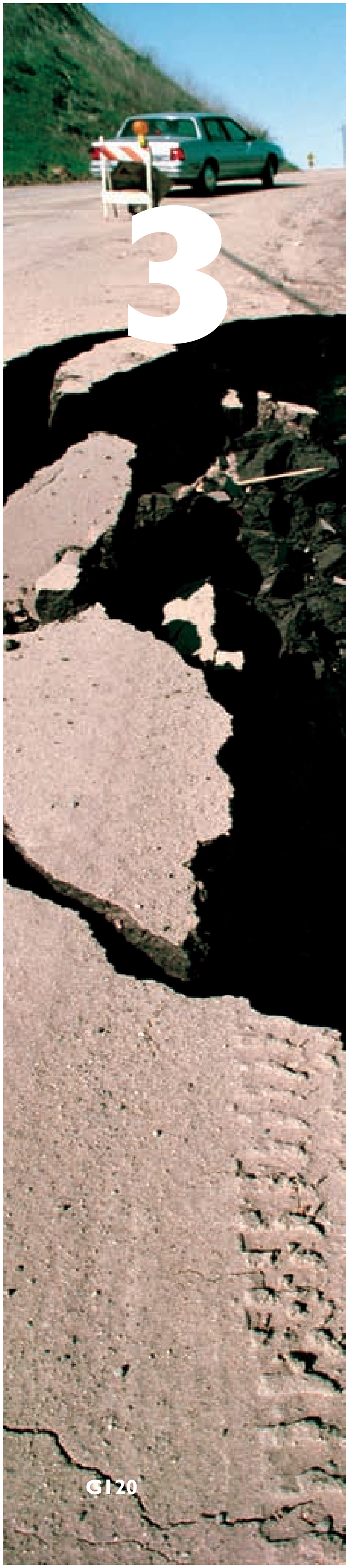


Earthquakes ...and Your Community

Getting Started

An average of about 350,000 earthquakes are detected on Earth each year.

- What causes an earthquake?
- How can an earthquake affect your community?

What do you think? In your notebook, draw a picture that shows a side view of the Earth's crust. Show what causes an earthquake, and how an earthquake can affect a community. Write a caption to explain your drawing. Be prepared to discuss your picture and ideas with your small group and the class.

Scenario

The following description of the 1906 San Francisco earthquake was written by author Jack London:

"Within an hour after the earthquake shock, the smoke of San Francisco's burning was a lurid tower visible a hundred miles away.

...There was no opposing the flames. There was no organization, no communication. The earthquake had smashed all the cunning adjustments of a twentieth century city. The streets were humped into ridges and depressions, and piled with the debris of fallen walls. Dynamite was lavishly used, and man crumbled many of San Francisco's proudest structures himself into ruins, but there was no withstanding the onrush of the flames. The troops were falling back and driving the refugees with them. From every side came the roaring of flames, the crashing of walls, and the detonations of dynamite."

Can you use your knowledge of earthquakes to develop a plan to ensure that your community would be prepared to deal with an earthquake?

Chapter Challenge

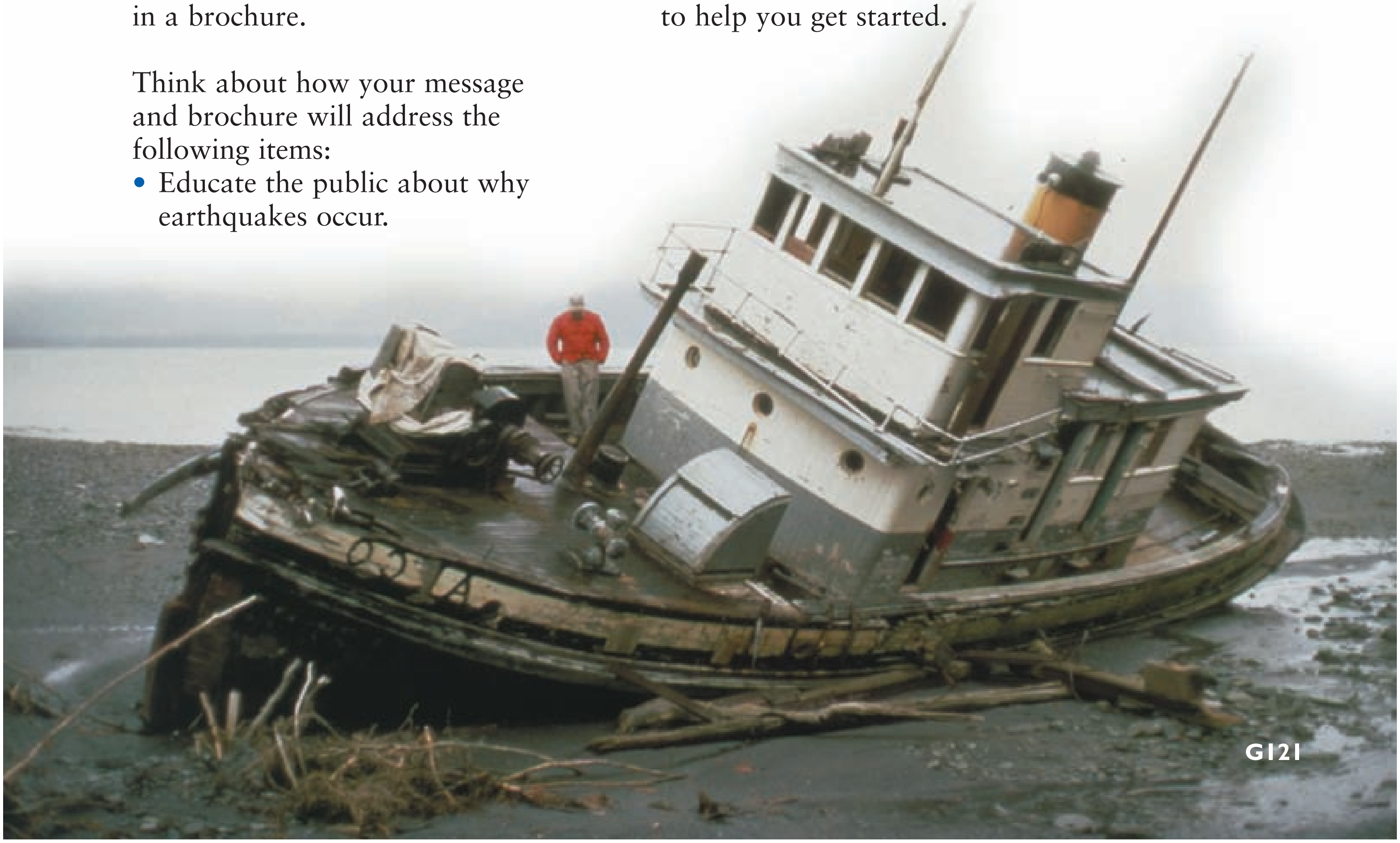
In many states of the U.S., damaging earthquakes can happen at any time. If you live along the Pacific Coast, in a mountain belt, or in the central Midwest, they may even be a very great hazard. Your community has asked your school to assess the earthquake hazard in your area and to find ways to reduce any damage. You have been asked to present these plans to the public as a public service message (video or audio) and in a brochure.

Think about how your message and brochure will address the following items:

- Educate the public about why earthquakes occur.
- Explain how earthquakes transmit energy.
- Explain the effects associated with earthquakes.
- Suggest ways to reduce the damage caused by earthquakes.

Assessment Criteria

Think about what you have been asked to do. Scan ahead through the chapter activities to see how they might help you prepare your brochure. Work with your classmates and your teacher to define the criteria for judging your work. Record all this information. Make sure that you understand the criteria as well as you can before you begin. Your teacher may provide you with a sample rubric to help you get started.



Activity 1 An Earthquake in Your Community

Goals

In this activity you will:

- Generate and describe two types of waves.
- Determine the relative speeds of compressional and shear waves.
- Simulate some of the motions associated with earthquakes.
- Infer the origin of earthquakes and the mechanism of transfer of seismic wave energy.

Think about It

In some earthquakes, the ground shakes back and forth so much that small objects are overturned, hanging objects and doors swing, and pictures are knocked out of plumb.

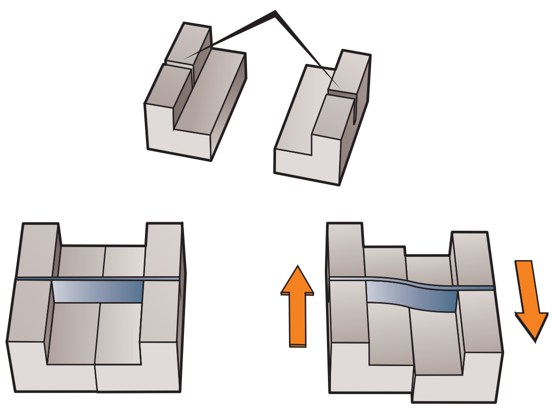
- If you have experienced an earthquake, describe your most vivid memory. If you have not experienced an earthquake, what would you expect to see, feel, and hear?

What do you think? Record your ideas about this question in your *EarthComm* notebook. Be prepared to discuss your response with your small group and the class.

Investigate

Part A: Rupture and Rebound

1. Obtain two "L"-shaped wooden blocks that have a slot cut in their short lengths, as shown in the diagram. Place the blocks so that the slots line up. Put a thin piece (less than 1 mm) of Styrofoam® into the two slots so that it connects the two blocks.



2. Put on your safety glasses. Holding the two blocks together, move the blocks parallel to each other, but in opposite directions. Do this very slowly. Gradually increase the offset between the blocks without breaking the Styrofoam.

   a) Record and sketch your observations in your notebook.

3. Continue to increase the offset until the Styrofoam snaps. Watch carefully what happens to the Styrofoam as it ruptures.

   a) Record and sketch your observations in your notebook.

   b) Did you feel a vibration in the wood? When?

Part B: A Thought Experiment on Rupture and Friction

1. The experiment with the Styrofoam strip shows some important things about the cause of earthquakes, but it's not a very realistic model of rocks. "Thought experiments" are experiments that scientists dream up and then run in their imagination, rather than in a real laboratory. They are a useful way to develop new ideas and insights into scientific problems. Here's a thought experiment that gets you closer to the real thing:

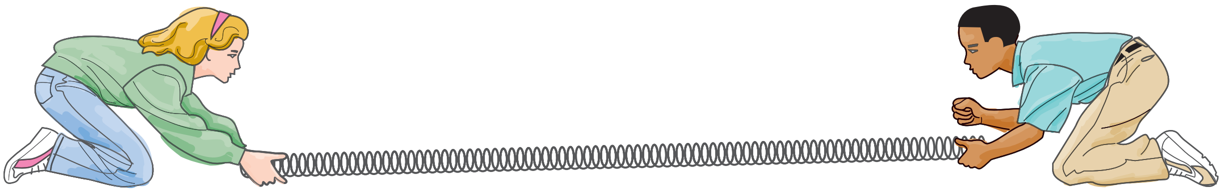
   Suppose you could make a "fake rock" that is just like a real rock, except that its strength is so much less that you can easily break it with your hands.

   Hold the two sides of the rock as you did to break the Styrofoam. As you gradually increase the sliding (shearing) force on the rock, it bends, just like the Styrofoam, but because it is much stiffer, like a real rock, you probably wouldn't be able to see the bending. Eventually the rock breaks along a line, and the two sides spring back to their original shape. "Seismic" waves are generated.

Styrofoam should not splinter. Do not substitute other material.

a) If you started to apply a shearing force again, with the two halves still pressed together, what do you think you would observe? Why would you need to exert some force to make the two halves slide past one another, even though they are already cut by a fracture?

b) Imagine pouring some liquid containing a bit of glue down into the fracture and waiting for the glue to set. The rock regains some of its strength. What happens when you again apply a greater and greater "sliding" force to the "healed" block of rock? Do you expect the force needed for rupture to be greater than originally, less, or the same? Why?



Part C: Vibration

1. Place a Slinky® on the floor. Have one person in your group hold one end of the Slinky and a second person hold the other end. Back away from each other so that the Slinky stretches out about 5 m long.

2. Have one person hold the end of the Slinky in a fist and then hit the back of the fist with the other hand. The palm should be facing the Slinky. Observe the motion of the Slinky. Repeat the pulse until each member of your group can describe the motion of the Slinky. Observe the direction the Slinky moves compared to the direction in which the pulse is moving.

   a) Record your observations.

3. With the Slinky stretched out about 5 m, have a person at one end quickly jerk the end of the Slinky back and forth (left to right). Observe the motions of the Slinky. Repeat the pulse until each member of your group can describe the resultant motion of the Slinky. Observe the direction the Slinky moves compared to the direction in which the pulse is moving.

   a) Record your observations.

4. To compare the two types of vibrations (wave motion) that you observed in the Slinky, stretch out two Slinkys along the floor, about 5 m. Starting at the same end at the same time, have one student strike their fist while the other student jerks the Slinky back and forth. Observe what happens. Try the movements several times until you are confident in your observations.

   a) Which of the two wave types arrives at the other end first (which one is faster)?

A stretched Slinky can move unpredictably when released. Spread out so that you can work without hitting anyone. Release the stretched Slinky gradually.

Reflecting on the Activity and the Challenge

In the experiments, you observed rupture, energy release, and energy transmission. These are the main processes in the occurrence of earthquakes.

In the experiment with the Styrofoam, you gradually applied a force to a solid material (the Styrofoam strip). The force caused the strip to bend. Bending like that is called elastic deformation. If you had removed the force before the strip broke, the strip would have returned to its original shape. Rocks in the Earth's crust behave in the same way. The material broke when the force exceeded the strength of the material. This instantly released the energy you had stored in the material by applying a force to bend it. In your model, you felt the sudden release of energy during rupture as a vibration in the wood. As the Styrofoam strip broke, its ends "jumped" a short distance in opposite directions, to straighten themselves out again.

In the thought experiment with the weak, fake rock, the force you applied caused the rock to rupture and slide along a fault plane. Friction along the fault plane made it necessary for you to apply a non-zero force to get the two halves to slide past one another even after they were cut by the fault. After the fault was partly healed, some force was still needed for the rock to slip along the fault plane again.

Energy can be transmitted from one place to another without permanent movement of the material. In the experiment with the Slinky, the energy of motion you put into the solid (the Slinky) by shaking it at one end was transmitted away from the source, without the Slinky changing its position after the waves had passed. Earthquake waves similar to the ones that you modeled carry the energy of the earthquake for long distances as they travel through the Earth.

Digging Deeper

WHAT IS AN EARTHQUAKE?

Earthquakes

An **earthquake** is a sudden motion or shaking of the Earth as rocks break along an extensive surface within the Earth. The rock masses on either side of the fault plane slip past one another for distances of as much as ten meters during the brief earthquake. The rocks break because of slowly built-up bending. The sudden release of energy as rock ruptures causes intense vibrations called **seismic waves** or earthquake waves.

Geo Words

earthquake: a sudden motion or shaking in the Earth caused by the abrupt release of slowly accumulated strain.

seismic (earthquake) waves: a general term for all elastic waves in the Earth, produced by earthquakes or generated artificially by explosions.

Geo Words

fault: a fracture or fracture zone in rock, along which the rock masses have moved relative to one another parallel to the fracture.

shear strength: the shear force needed to break a solid material.

elastic rebound: The return of a bent elastic solid to its original shape after the deforming force is removed.

friction: the force that resists the motion of one surface against another surface.

focus: the point of an earthquake within the Earth where rupture first occurs to cause an earthquake.

epicenter: the point on the Earth's surface directly above the focus of an earthquake.

fault scarp: the cliff formed by a fault that reaches the Earth's surface.

Geoscientists explain the occurrence of earthquakes in the following way. A **fault** is a surface between two large blocks or regions of rock, along which there has been rupture and movement in the past. Faults are very common in the rocks of the Earth's crust. Large-scale forces within the Earth's crust push the fault blocks in opposite directions. Most of these forces are caused by the movements of the Earth's plates.

As the forces gradually build up over time, the blocks are bent on either side of the fault, the same as with the Styrofoam strip. The region of bending can extend for very long distances away from the fault. All rocks have a shear strength. The **shear strength** of a rock is the force that is needed to break the rock when it is acted upon by forces in two opposite directions. Eventually the forces overcome the shear strength of the rock, and the rock breaks along the fault plane. The blocks then suddenly slip for some distance against each other to undo the bending, and stored energy is released. The straightening movement is called **elastic rebound**.

Usually, the rocks in a fault zone have already been ruptured by earlier earthquakes. Why don't they just slip continuously as force is applied? The answer is that in some places, they do slip continuously. In most places, however, the fault becomes "locked" and doesn't move again for a long time. There are two reasons for this. One reason is that there is a lot of **friction** along the fault plane, because the rock surfaces are rough and are pressed together by the great pressure deep in the Earth. You can see for yourself how effective this rock friction is, by gluing sandpaper to two wooden blocks and then trying to slide the sand-papered surfaces past one another while you squeeze the blocks together. The other reason is that new minerals tend to be deposited along the fault by slowly flowing water solutions. This new mineral material acts as a "cement" to restore some of the shear strength of the rock.

Earthquakes usually occur at some depth below the surface. The place in the Earth along the fault where rupture occurs is called the earthquake **focus**, as shown in *Figure 1*. The **epicenter** is the geographic point on the Earth's surface directly above the focus. Once a fracture starts, it spreads rapidly in all directions along the fault plane. It often reaches the Earth's surface. Where it does, the motion on the fault can cause a sharp step in the land surface, called a **fault scarp**. Fault scarps can be as much as a few meters high. Horizontal motions along a fault can cause roads or fences to be offset, by as much as 10 to 15 m.

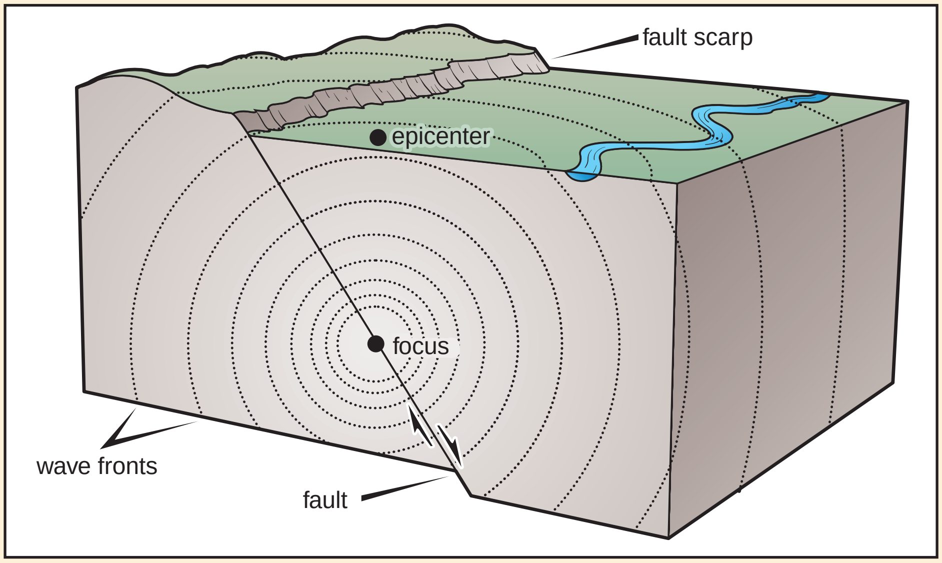


Figure 1 The relationship between the focus and the epicenter of an earthquake.

Earthquake or Seismic Waves

When an earthquake occurs by rupture along a fault, the elastic energy of bending is released and seismic waves spread out in all directions from the focus. Earthquakes produce several kinds of seismic waves. The different kinds of waves travel through rocks at different speeds, and each kind of wave causes a different kind of motion in the rock as it passes by. The various kinds of waves arrive at some distant point on the Earth at different times, depending on their relative speed and their path though the Earth. (See *Figure 2*.)

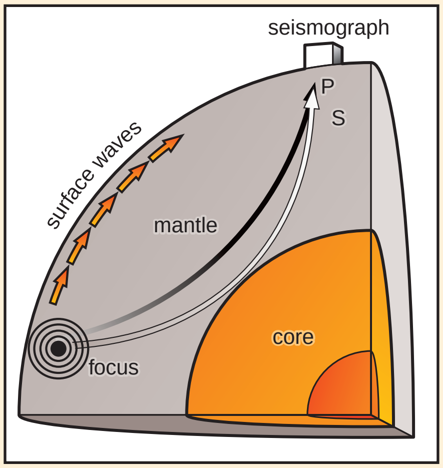


Figure 2 Earthquakes produce several types of seismic waves.

Geo Words

primary wave (P wave): a seismic wave that involves particle motion (compression and expansion) in the direction in which the wave is traveling.

secondary wave (S wave): a seismic wave produced by a shearing motion that involves vibration perpendicular to the direction in which the wave is traveling. It does not travel through liquids, like the outer core of the Earth.

surface wave: a seismic wave that travels along the surface of the Earth.

Compressional waves (*Figure 3a*) cause rapid compression and expansion of rock as they pass through the Earth. As the waves pass, the rock material is moved back and forth in the direction of wave motion. Compressional waves are the first to reach a location away from the focus, so they are called **primary waves**, or just P waves. P waves are similar to sound waves. They can move through solids, liquids, and gases. They move through solid rock at a speed of about five kilometers per second, or about fifteen times the speed of sound in air.

Shear waves arrive at a location after compressional waves, so they are called **secondary waves**, or just S waves. Shear waves (*Figure 3b*) move rock material at right angles to the direction of their motion. S waves can travel only through solids, not through fluids. They move through rock at a speed of about three kilometers per second.

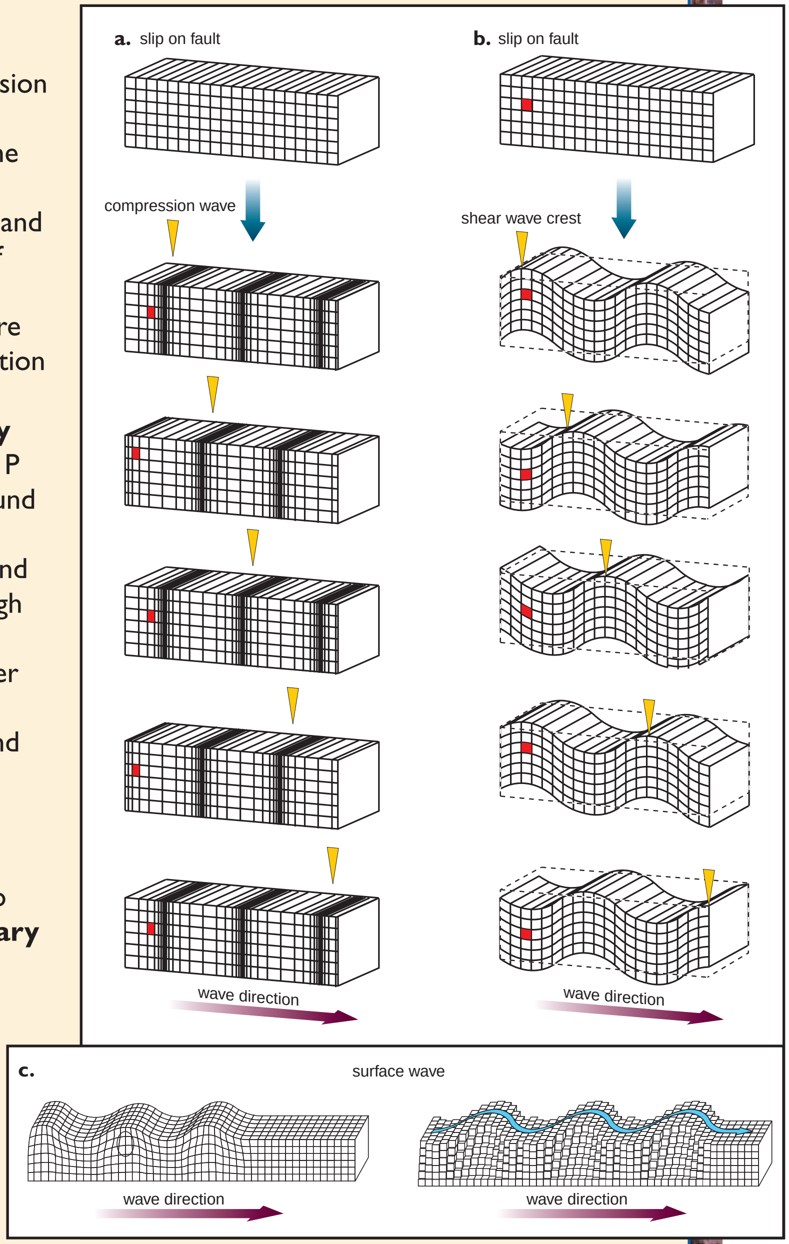


Figure 3 This diagram shows how **a.** primary (compressional), **b.** secondary (shear), and **c.** surface waves move through the Earth.

Check Your Understanding

1. What is an earthquake?
2. Explain how seismic waves are generated by an earthquake.
3. What is the relationship between the focus and the epicenter of an earthquake?
4. Use a diagram to describe the differences between P waves, S waves, and surface waves.
5. Rank P waves, S waves, and surface waves in order from fastest to slowest.

Surface waves, which travel along the Earth's surface, are the last to arrive at a location. They travel slower than S waves. There are two kinds of surface waves. One kind creates an up-and-down rolling motion of the ground, very much like a wave on a water surface (*Figure 3c.i*). The other kind of surface wave shakes the ground sideways (*Figure 3c.ii*). Surface waves usually cause the most movement at the Earth's surface, and therefore the most damage.

Understanding and Applying What You Have Learned

1. What kinds of motion would you expect to feel in an earthquake?
2. What effects might earthquake motions have on buildings, roads, and household furnishings?
3. Of the types of earthquake waves discussed in this section, which do you think are the most dangerous? Why?
4. Many people have some common beliefs about earthquakes. One of these is that earthquakes occur more frequently in areas of warm climates.
    a) How would you design an investigation that might test this idea?
    b) Do you have information available to you that either supports or contradicts this idea?
    c) Write a short paragraph either supporting or refuting this belief.
5. What other ideas about earthquakes did you have before doing these activities that were either supported or contradicted by what you have learned through your investigation? Describe your original ideas and how they were either confirmed or refuted.
6. Some faults are frequently active and produce numerous small earthquakes. Other faults are rarely active but produce large earthquakes. Based on the activities you completed, propose factors that might influence the number and size of earthquakes produced by a fault.
7. In the rupture activity, you provided the energy needed to break the styrofoam. Use this idea to describe why earthquakes reveal that Earth is a dynamic planet.

Preparing for the Chapter Challenge

Write a background summary for the brochure you will prepare for your **Chapter Challenge**. Include a concise, simple, but accurate explanation for the cause of earthquakes, how they transmit energy, and how different types of seismic waves move. Be sure to address any common beliefs that you may know to be false. This section should be no longer than one page. Include diagrams as appropriate.

Inquiring Further

1. **Forming questions to investigate**

   Write down other questions you have about the causes of earthquakes and their effects. How would you go about gathering information to answer these questions? Write your ideas in your notebook.

2. **Using seismic waves to study the Earth's interior**

   How do we know about the structure and composition of the interior of the Earth? Study of the distribution and effects of earthquakes, and especially of the transmission of seismic waves, has enabled geoscientists to develop many answers. To learn more about the details of the Earth's structure revealed by the study of seismic waves, visit the *EarthComm* web site.

3. **Using seismic waves to explore for oil and gas**

   Understanding the behavior of seismic waves allows geoscientists to use them as tools to study deep layers of the Earth. Find out how exploration geologists use seismic waves to draw inferences about the layers of sedimentary rock in which they find oil and gas deposits. Consult the *EarthComm* web site.

4. **Earth science careers**

   Do you think you would like to study earthquakes for a career? To see what a seismologist does at work, visit the *EarthComm* web site.

Marine seismic vessel.